Ideal Gases

Question paper 3

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Ideal Gases
Sub Topic	
Paper Type	Theory
Booklet	Question paper 3

Time Allowed: **72 minutes**

Score: **/60**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 **(a)** The volume of an ideal gas in a cylinder is $1.80 \times 10^{-3}\,m^3$ at a pressure of $2.60 \times 10^5\,Pa$ and a temperature of 297 K, as illustrated in Fig. 2.1.

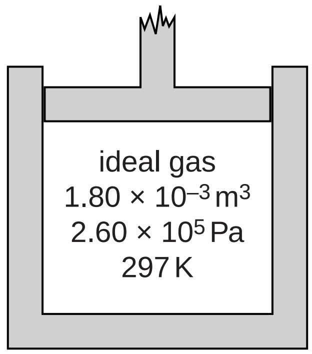

Fig. 2.1

The thermal energy required to raise the temperature by 1.00 K of 1.00 mol of the gas at constant volume is 12.5 J.

The gas is heated at constant volume such that the internal energy of the gas increases by 95.0 J.

(i) Calculate

1. the amount of gas, in mol, in the cylinder,

amount = ... mol [2]

2. the rise in temperature of the gas.

temperature rise = ... K [2]

(ii) Use your answer in **(i) part 2** to show that the final pressure of the gas in the cylinder is 2.95×10^5 Pa.

[1]

(b) The gas is now allowed to expand. No thermal energy enters or leaves the gas. The gas does 120 J of work when expanding against the external pressure.

State and explain whether the final temperature of the gas is above or below 297 K.

....

....

....

.... [3]

2 An ideal gas has volume V and pressure p. For this gas, the product pV is given by the expression

$$pV = \tfrac{1}{3}Nm\langle c^2\rangle$$

where m is the mass of a molecule of the gas.

(a) State the meaning of the symbol

(i) N,

.... [1]

(ii) $\langle c^2\rangle$.

.... [1]

(b) A gas cylinder of volume $2.1 \times 10^4\,\text{cm}^3$ contains helium-4 gas at pressure 6.1×10^5 Pa and temperature 12 °C. Helium-4 may be assumed to be an ideal gas.

(i) Determine, for the helium gas,

1. the amount, in mol,

amount = ... mol [3]

2. the number of atoms.

number = ... [2]

(ii) Calculate the root-mean-square (r.m.s.) speed of the helium atoms.

r.m.s. speed = ... $m\,s^{-1}$ [3]

3 **(a)** The kinetic theory of gases is based on some simplifying assumptions.
The molecules of the gas are assumed to behave as hard elastic identical spheres.
State the assumption about ideal gas molecules based on

(i) the nature of their movement,

....

.... [1]

(ii) their volume.

....

....

.... [2]

(b) A cube of volume V contains N molecules of an ideal gas. Each molecule has a component c_X of velocity normal to one side S of the cube, as shown in Fig. 2.1.

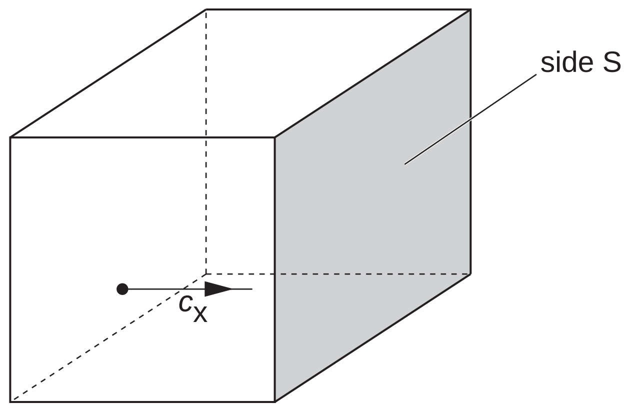

Fig. 2.1

The pressure p of the gas due to the component c_X of velocity is given by the expression

$$pV = Nmc_X^2$$

where m is the mass of a molecule.

Explain how the expression leads to the relation

$$pV = \frac{1}{3}Nm\langle c^2\rangle$$

where $\langle c^2\rangle$ is the mean square speed of the molecules.

[3]

(c) The molecules of an ideal gas have a root-mean-square (r.m.s.) speed of 520 m s^{-1} at a temperature of 27 °C.

Calculate the r.m.s. speed of the molecules at a temperature of 100 °C.

r.m.s. speed = ... m s^{-1} [3]

4 **(a)** One assumption of the kinetic theory of gases is that gas molecules behave as if they are hard, elastic identical spheres.

State two other assumptions of the kinetic theory of gases.

1. ....

....

2. ....

....
[2]

(b) Using the kinetic theory of gases, it can be shown that the product of the pressure *p* and the volume *V* of an ideal gas is given by the expression

$$pV = \tfrac{1}{3}Nm\langle c^2\rangle$$

where *m* is the mass of a gas molecule.

(i) State the meaning of the symbol

1. *N*,

....[1]

2. $\langle c^2\rangle$.

....[1]

(ii) Use the expression to deduce that the mean kinetic energy $\langle E_K\rangle$ of a gas molecule at temperature *T* is given by the equation

$$\langle E_K\rangle = \tfrac{3}{2}kT$$

where *k* is a constant.

[2]

(c) **(i)** State what is meant by the *internal energy* of a substance.

....

....

.... [2]

(ii) Use the equation in **(b)(ii)** to explain that, for an ideal gas, a change in internal energy ΔU is given by

$$\Delta U \propto \Delta T$$

where ΔT is the change in temperature of the gas.

....

....

.... [2]

5 **(a)** State what is meant by the *Avogadro constant* N_A.

....

....

....[2]

(b) A balloon is filled with helium gas at a pressure of 1.1×10^5 Pa and a temperature of 25 °C.
The balloon has a volume of $6.5 \times 10^4 \text{ cm}^3$.
Helium may be assumed to be an ideal gas.

Determine the number of gas atoms in the balloon.

number = ... [4]

6 **(a)** State what is meant by a *mole*.

....

....

.... [2]

(b) Two containers A and B are joined by a tube of negligible volume, as illustrated in Fig. 2.1.

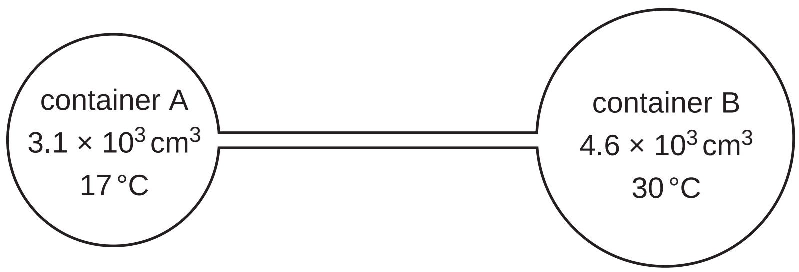

Fig. 2.1

The containers are filled with an ideal gas at a pressure of 2.3×10^5 Pa.
The gas in container A has volume 3.1×10^3 cm^3 and is at a temperature of 17 °C.
The gas in container B has volume 4.6×10^3 cm^3 and is at a temperature of 30 °C.

Calculate the total amount of gas, in mol, in the containers.

amount = ... mol [4]

7 **(a)** **(i)** State the basic assumption of the kinetic theory of gases that leads to the conclusion that the potential energy between the atoms of an ideal gas is zero.

....

.... [1]

(ii) State what is meant by the *internal energy* of a substance.

....

....

.... [2]

(iii) Explain why an increase in internal energy of an ideal gas is directly related to a rise in temperature of the gas.

....

....

.... [2]

(b) A fixed mass of an ideal gas undergoes a cycle PQRP of changes as shown in Fig. 2.1.

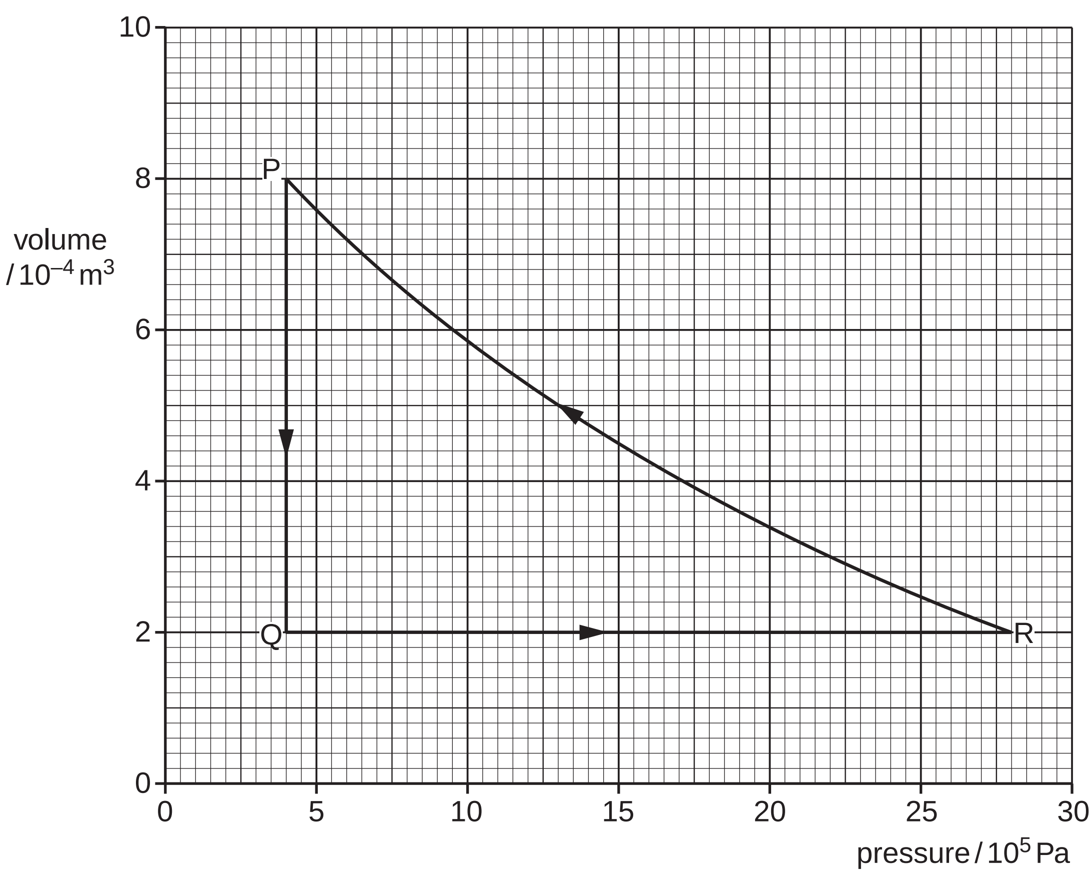

Fig. 2.1

(i) State the change in internal energy of the gas during one complete cycle PQRP.

change = ... J [1]

(ii) Calculate the work done on the gas during the change from P to Q.

work done = ... J [2]

(iii) Some energy changes during the cycle PQRP are shown in Fig. 2.2.

change	work done on gas / J	heating supplied to gas / J	increase in internal energy / J
P → Q	....	–600	....
Q → R	0	+720	....
R → P	....	+480	....

Fig. 2.2

Complete Fig. 2.2 to show all of the energy changes. [3]